

TEKSCOPE




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Cover: The cathode ray tube display generated by the new TEKTRONIX LA 501 Logic Analyzer. Note the sixteen traces are separated into groups of four traces each for easy identification.

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Marshall Borchert

16-channel logic analyzer

If you have ever had to find an intermittent fault in an electrical circuit you know how frustrating and time consuming it can be. On the other hand, if you know some techniques for locating such faults faster than your buddies you know how it feels to be a hero. It doesn't matter much what kind of electrical circuits we are talking about. But the more complex the equipment is, the bigger the problem, and most complex electrical equipment is usually digital equipment. There are some new instruments for isolating faults in complex digital equipment and a LOGIC ANALYZER is the most sophisticated of the bunch. It has top billing among the top performers, and attracts design engineers as well as service people. Tektronix makes one . . . the LA 501. We would like to tell you about Logic Analyzers in general and about the LA 501 in particular.

There are several basic kinds of Logic Analyzers and they can be distinguished by the kind of display they are capable of producing. Some have numerous lights that indicate a sequence or a combination of ONES and ZEROS. Some can display ONES and ZEROS as numbers on a crt screen or video monitor as though they were on a printed page. Others can display ONES and ZEROS in the form of HIGHS and LOWS in a multi-trace timing diagram on a crt screen. The LA 501 belongs in the timing diagram category. Instruments of that kind can capture and display the most data as well as relate it to units of time.

Probably the most important characteristic of Logic Analyzers is that they can capture digital data prior to the first indication of a circuit fault. Then they can display what was captured for as long as you like. That way the events which led up to the moment of failure may be analyzed. An ordinary storage oscilloscope can't do that. For unpredictable one-shot events like an intermittent failure, oscilloscopes can only show what happens after receiving a trigger signal. Logic Analyzers can also be operated to capture data after receiving a trigger signal and that may be important at times, but it is not very unique.

The trick in capturing digital data leading up to a fault is to continually store new data while erasing older data. It is like having a continuous-loop tape recording of a conversation. As soon as the loop of tape has been fully recorded the older conversation is erased as the newest words are recorded. If you had a way of recognizing a lie in the conversation the instant it was fully told, you could stop recording at that instant and repeatedly play back the whole thing. To record a faulty binary signal in a similar way you can clock it into a shift register, allowing old data to spill out as soon as the register is filled. Then, at anytime, you can shut off the input, recirculate the contents of the register and repeatedly display the contents as a sequence of

ONES and ZEROS. The pattern will represent the history of data flow just prior to shutting down the recording process. By using any signal that may be an early symptom of a fault as a trigger, the recording can be stopped and events leading to the fault displayed. Recording doesn't have to be stopped instantly. It may be allowed to continue for a select number of clock cycles if later events may be significant.

The second most important characteristic of Logic Analyzers is that they have many input channels. Four, eight, or sixteen channels is common for analyzers designed to display recorded binary signals as a timing diagram on a crt screen. Data on each of the input channels is clocked and recorded simultaneously, then stored in independent memories. That way any input signal may be compared with any other to show the logic states that existed at a prior moment. That is what a timing diagram does.

Multichannel recording is of critical importance when data is transmitted over more than one line. For example, 4 lines for BCD, or 7 lines plus 1 parity line for ASCII characters, etc. In such cases it is the combination of HIGHS or LOWS that may exist at any moment on a set of such lines, which indicates a faulty or normal condition. But multi-channel recording does not need to be restricted to binary signals on lines that

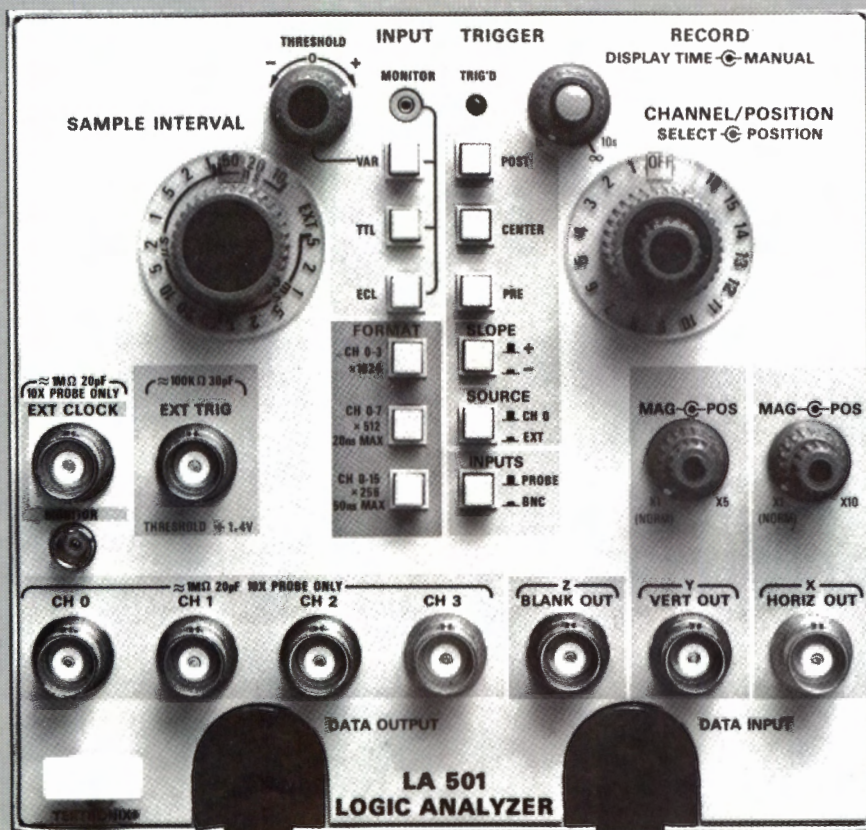


Fig. 1. The LA 501 Logic Analyzer.

transmit data words. An engineer debugging a new design may want to compare any binary signal with a bunch of others that have a predictable dependence. When you are looking for a needle in a haystack and you only get a crack at it occasionally it is nice to be able to examine a big chunk of the stack at one time.

Clocking samples of a binary signal

Logic Analyzers repeatedly "sample" the voltage state of any binary signal where a data-input probe is placed, by comparing it against a preset level that is between a HIGH and a LOW. One probe is used for each channel. Comparisons are simultaneous at all inputs, so the voltage level at different inputs during any sample may be stored and displayed. Comparisons in some Logic Analyzers may be slaved to either an internal clock signal or an external clock signal. An external clock signal is commonly the same one employed in the equipment under test. That way clocking is synchronous with whatever is going on in the equipment under test even if the clock signal is aperiodic, and the most data is acquired with the least number of clockticks. Such a clock signal is usually called a system clock.

The internal clock frequency is usually selectable. The usual practice is to select a clock period that is at least three times shorter than the clock period of the

equipment under test. That permits at least two comparisons to be made of each new HIGH or LOW level following any transition in the signal being sampled. An analyzer clock period that is two times shorter than the clock period in the equipment under test will allow at least one sample to be taken of every state of the binary signal. By using a considerably higher clock frequency than the system clock, glitches and noise spikes may be recorded and displayed. With a 100 MHz clock, glitches as narrow as 15 ns may be recorded reliably.

Each time a binary signal is sampled it is actually only compared to a preset, threshold voltage level to see whether the voltage is HIGH or LOW. If the signal voltage is higher than the threshold voltage a HIGH is clocked into a storage register. In the opposite case a LOW is stored. The result is a series of HIGHS and LOWS that shift through each register and resemble the pattern of the original binary signal sampled. The clock does not have to be synchronous with the transitions of the sampled signal for the stored signal to be a reasonable replica of the input signal. Transitions in any replica will differ from the original signal by no more than the period of one clock signal cycle. That interval is a resolution limit. See Figure 2.

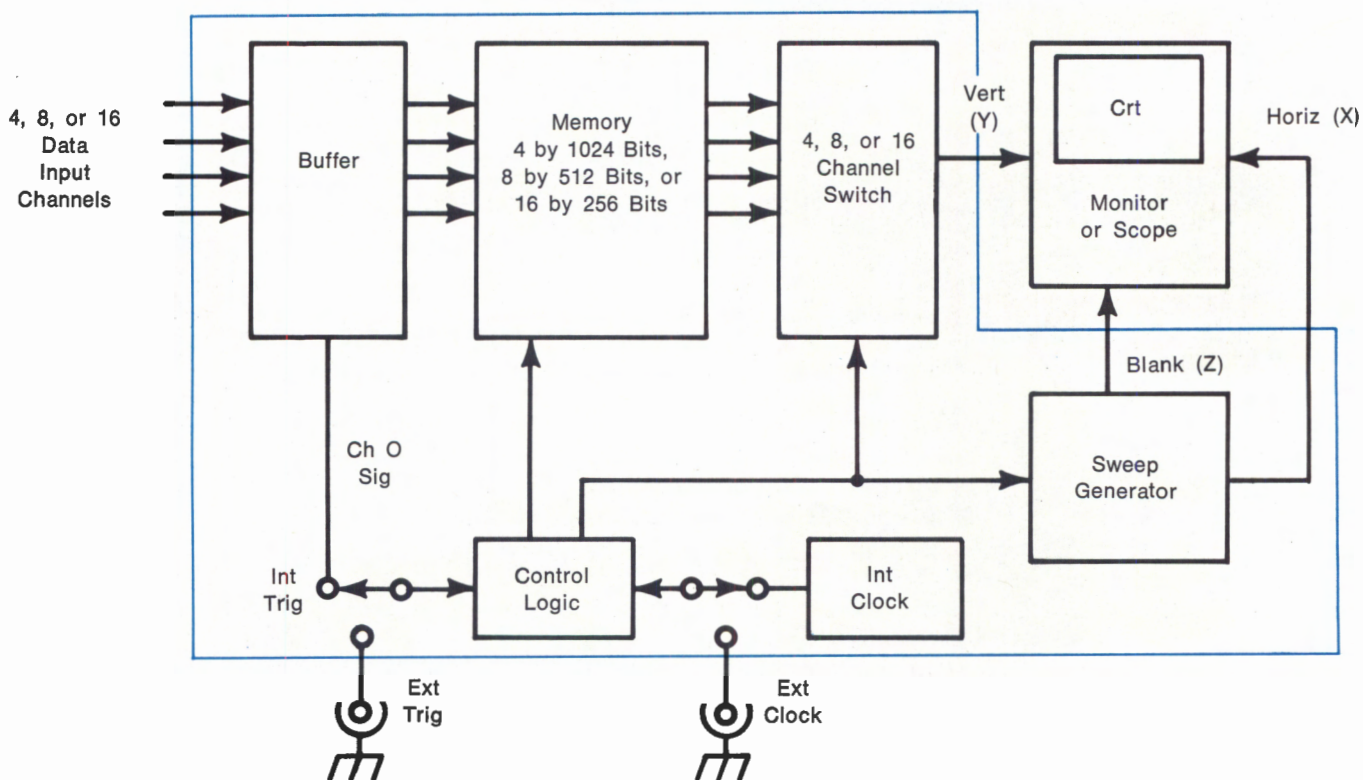


Fig. 2. Simplified block diagram of the LA 501.

Separate versus built-in Cathode Ray Tubes

Some Logic Analyzers using a crt for readout have the crt built in, and others must be hooked up to a monitor crt or oscilloscope. The main reason for not including a crt with every logic analyzer is that they would be bigger and more expensive. Besides, Logic Analyzers are sometimes operated for hours merely waiting for a faulty condition to manifest itself. A monitor or oscilloscope is not needed during such periods and may be attached after the error information has been captured. The information is not altered by making the hook-up later. In fact, the display is always a replica of what has been previously stored in memory. If you now have a general idea of how Logic Analyzers work we'd like to tell you about the LA 501 . . . the first Logic Analyzer Tektronix has offered.

The LA 501 Logic Analyzer

The LA 501 is constructed as a plug-in for the TEKTRONIX TM 500 Series mainframes. That lets you plug-in an oscilloscope monitor (SC 502) when and if you want to. It also allows you to add optional capabilities with one of the many TM 500 Series plug-ins. For example, with the DD 501 plug-in you can delay triggering by any number of clock pulses up to 100,000. This capability is built into some logic analyzers, but it is an unnecessary expense when not needed.

Sometimes it is important to store 16 binary signals, and sometimes 4 or 8 signals are enough. The LA 501 gives you a choice of 4, 8, or 16 without sacrificing the total 4k bit-storage capacity. You can store 1024 bits per channel on up to 4 channels, 512 bits per channel on up to 8 channels or 256 bits per channel on up to 16 channels. There is a sacrifice in the maximum permissible clock frequency when 8 or 16 channels are stored, however. The maximum internal clock frequency of the LA 501 is 100 MHz with 4 channels, 50 MHz with 8 channels, and 20 MHz with 16 channels. For external clock signals 50 MHz is the limit for both 4 and 8 channels, and 20 MHz is the limit when using 16 channels.

The LA 501 can be operated to cease recording very shortly after receiving a trigger signal and this is probably the most common mode. In that mode all but about the last 6% of each trace in the display will depict pre-recorded data and will resemble an oscilloscope display that was pretriggered. But you may also operate the LA 501 so that either 50% or 94% of the recorded data occurs after the trigger point. For recording only data that arrives after the trigger point a separate delay generator, such as the DD 501 Digital Delay unit should be used.

The new SC 502 Oscilloscope is a plug-in for the TM 500 Series mainframes and makes a good companion

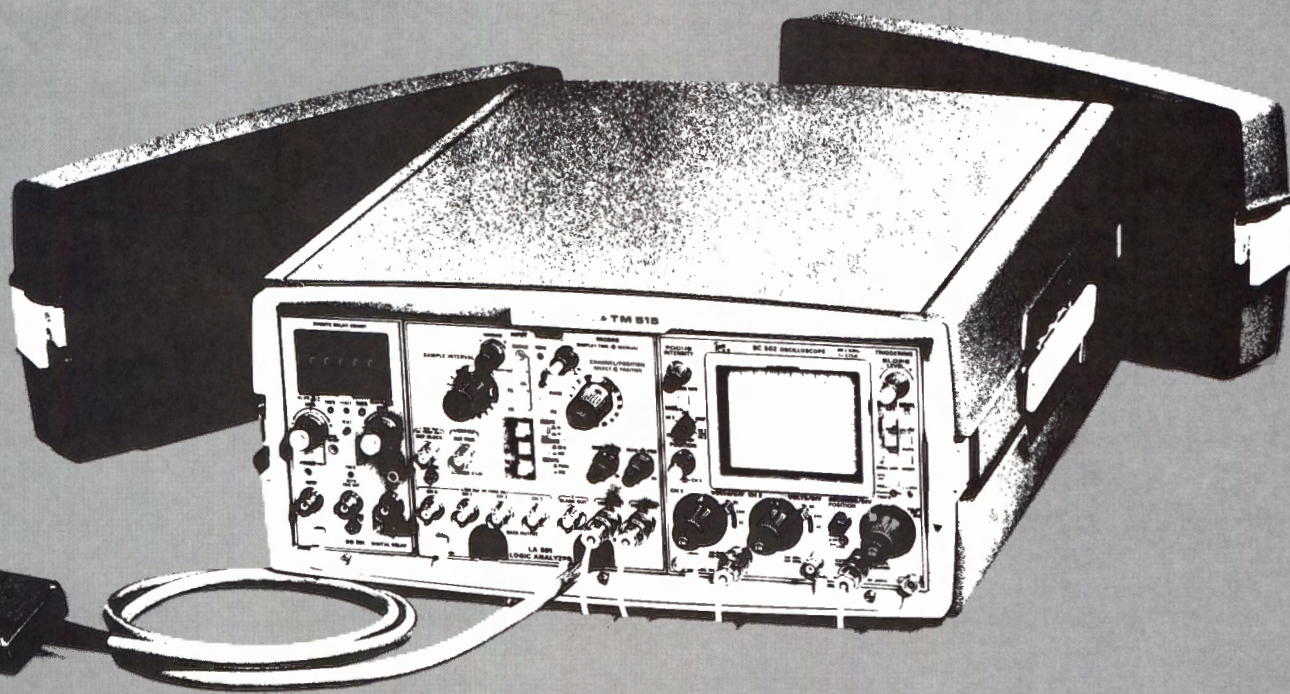


Fig. 3. The LA 501 with a companion oscilloscope and digital delay unit housed in a TM 515 Traveler Mainframe.

monitor for the LA 501 Logic Analyzer. And the new suitcase-style TM 515 Mainframe makes an excellent integrated, portable, shippable package of the LA 501 and SC 502 when plugged in side by side. There is even room and power available for a DD 501 Digital Delay plug-in in the same mainframe. Either way hook-up is extremely simple. Only three coaxial cables with BNC fittings are required. One is for vertical deflection, one is for horizontal deflection, and one is for the crt z-axis to blank the beam during retrace. A TM 503 is a suitable power supply and mainframe for the LA 501 when a separate oscilloscope or monitor is used to display the recorded data.

Putting up to 16 traces on the face of a small monitor or oscilloscope may seem to be a little crowded. However, several novel things were done in the LA 501 to organize and clearly display that data. The traces are arranged in groups of four with a fixed amount of separation between each trace. The traces correspond to channels 0 through 15, reading from the top. All 16 traces may be moved up and down together with one vertical positioning control. Signal size, and separation between traces, may be expanded up to 5 times for a close look at any group. A variable horizontal magnifier having up to 10X gain may then be used to take a close look at time coincidence of transitions, etc. Both vertical and horizontal magnification occur at center screen regardless of how a display is positioned, so it is very hard to get lost.

Especially useful is a feature which lets you select any one of the input signals and position it up and down independently. That lets you make a meticulous comparison between any two of up to 16 signals. By merely superimposing the signal from any one of the channels onto any other, practically all errors caused by trying to relate widely separated signals are eliminated. Eliminated also is the strain of trying. With these features all traces remain easily identified with the input channel at all times. You can look at the whole forest, a section of the forest, or one tree at a time, and never get lost.

Up to four LA 501's may be slaved together, permitting you to simultaneously record 64 binary signals for an interval equal to 256 clock pulses. If more samples are required, you can record 32 signals with 512 clock pulses, or 16 signals with 1024 clock pulses.


What about triggering?

Deciding what to use for a triggering signal can be a problem for anyone using a logic analyzer. One should remember that unlike oscilloscopes, the triggering signal does not have to occur ahead of what you want to display. Some digital equipment produces a unique error signal any time a faulty condition occurs. When

such a test signal is available it may be just the ticket. At other times, the first sign of a fault may be when the state of several lines is in unique combination. To trigger the LA 501 when the last several lines goes to a state which makes the combination unique, a data word recognizer can be used to generate a special triggering signal. Triggering with a word recognizer is sometimes called combinatorial or pattern triggering. No word recognizer circuits are built into the LA 501, but one or more four-line TEKTRONIX 821 Word Recognizers may be used to generate the needed signal. That way all channels in the analyzer are available for normal duty at all times.

A multiple-input probe cable is available for the LA 501. Up to 16 probes are attached to the cable and they have very small tips for attaching to points that are very small or closely spaced. When the circuits being tested can't stand a 100-k Ω , 45-pF load, up to four 10-M Ω oscilloscope probes may be substituted for the first four of the 4, 8, or 16 channels. That way the expense of using oscilloscope probes for all inputs is avoided. The signal on channel 0 is available as an internal triggering signal.

Display the recordings

Some people will wonder how sixteen channels of binary data may be recorded simultaneously, then displayed on one crt screen with one beam. The LA 501 displays all of the data sequentially, one channel at a time, one trace at a time, at a rate high enough so the traces appear steady and without a flicker. After each sweep occurs, a staircase signal moves the beam down one step during the retrace interval. Then, as the beam is swept across again, data from the next storage register moves the beam up and down a small fixed amount to correspond with the HIGHS and LOWS of the stored binary data for that channel. The whole sequence repeats after all selected storage registers have been scanned. 

LA 501

pinpoints

defective

microprocessor

The four photos shown here illustrate how the LA 501 was used to isolate a circuit malfunction. The defective equipment was in the design stage. It was digital equipment that would not respond properly to a very simple program requiring it to sequence through the first 16 addresses, then do a jump. The example is real, and was chosen for its simplicity so it might be easily explained and understood.

The only way to get some signal data to study was to manually assert the **RESTART** command. With an oscilloscope, you could see one trace each time the command was issued, but no other coherent display. Center-screen triggering was chosen so you could display events well ahead of the trigger point, if necessary. To reduce screen clutter, only eight inputs were chosen to record and look at. The signals on other input lines could be displayed at will later, if desired, since a suitable trigger was available whenever needed.

The system clock signal ($\phi 1$, $\phi 2$, $\phi 2$ EXTEND), were displayed on the three inputs, and the plan was to look at all of the address counter lines in groups of five. The LA 501 asynchronous clock was set for $0.2 \mu s$ intervals because the shortest pulses in the defective equipment had a duration of $1 \mu s$. This would give us four or five samples of the narrowest pulses. With eight traces being displayed, 512 samples would be taken of each of the eight input signals. From a basic knowledge of what the counter line signals should look like, the circled section of address counter line A3 (Figure A) was recognized to be in error. The circled section of the $\phi 2$ clock signal on which A3 depends, corresponds to that interval.

Figure C shows the $\phi 2$ clock signal positioned directly above A3 for a close comparison. The A3 pulse is shown to be ending prematurely, coincident with the first downgoing pulse edge following initial turn on. Since the counting function was performed by a microprocessor IC, it was simply replaced by a new one and the circuit worked properly.

The defective component was located in a relatively short time using the LA 501 Logic Analyzer. It would have taken much longer using any other means.

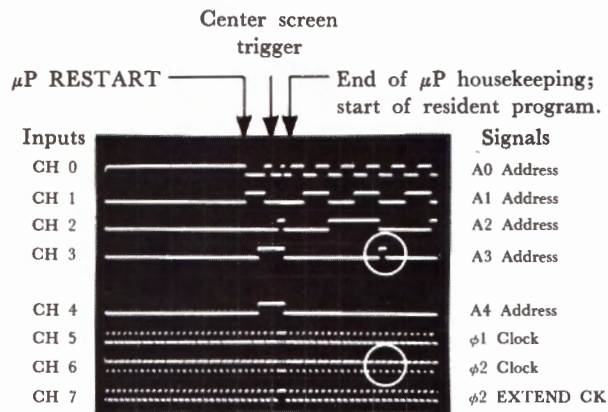


Figure A. Unexpanded replicas of $100 \mu s$ segment of eight binary signals, recorded simultaneously on a one-shot basis.

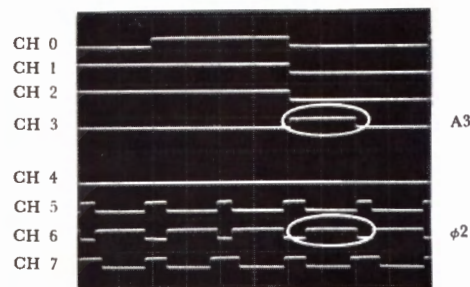


Figure B. Horizontal expansion of same signals as in Figure A. positioned to keep regions of interest on screen.

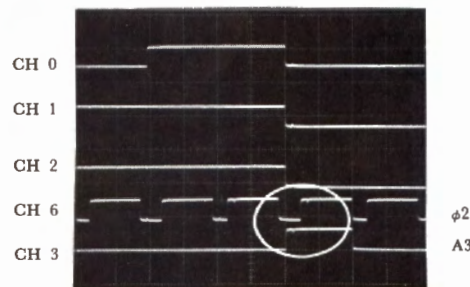


Figure C. Vertical expansion with $\phi 2$ positioned directly above A3. The A3 pulse should not end when it does.

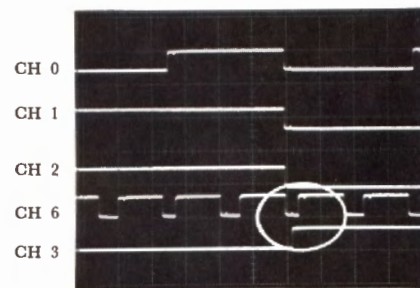


Figure D. Same as Figure C. except the defective microprocessor IC is replaced by a good one.



Stan Foss

Display monitors— through the looking glass

There is a wonderland of things you can see on a cathode ray tube screen besides traces. Picture tube is another name for a crt, but crts are more than a TV screen. Crts may serve as a blackboard, projection screen, graph paper, camera, or magnifier of the microscopic. They can freeze action, slowly accumulate and fit together parts of a picture, or animate the theoretical or complex. When we put the right crt in a package that supplies the special voltages, amplifiers, and beam intensity control essential to its operation, we have something called a display monitor. It is a modest name, deceptively ordinary. So was the looking glass in Alice in Wonderland.

The Auger microprobe and Gamma camera are examples of two widespread applications for display monitors. They illustrate well two of the most often used displays—the raster scan and the random scan.

The scanning Auger microprobe

For analyzing the chemistry and electrical conductivity of extremely small surfaces, the Auger microprobe (Fig. 1) may be used. Auger signals are recorded and processed by the system, to determine composition and electrical characteristics of a surface layer.

By scanning a surface with a finely-focused electron beam, a variety of graphic and pictorial information about the nature of the surface may be displayed. Some electrons from the beam will be reflected. The number reflected, the energy they retain, and the angle they take, will vary depending on the surface. Electrical signals proportional to these factors may be derived and displayed. These are called Auger signals. Employing a display monitor, these signals can be used for microscopic analysis with a surface depth resolution on the order of a millionth of a millimeter (10 angstroms). When a series of microscopic scans are combined in this manner, we have a raster scan. Examples of situations where composition of the surface layer may be analyzed in this manner include: alloys used in dental repair, bearings, and in determining the conductivity of junctions and other critical points on an integrated circuit.

The Gamma camera

The Gamma camera looks into people like an X-ray camera, and its display monitor shows us where radioactive material in the body is located and concentrated. A small amount of radioactive material is first injected into a patient's bloodstream, and Gamma particles are emitted from it. Each particle produces a tiny flash of light when it impinges on the camera's scintillation crystal, and each flash is collimated and sensed by a particular photocell. The location of each photocell corresponds to a point in the patient's body that is under scrutiny of the camera. Each time a photocell receives a flash of light, a corresponding point is illuminated on the display monitor by aiming the crt beam with position information from the Gamma camera, and turning the beam on momentarily. The time between receipt of successive Gamma particles is completely random, as is the sequence in which dots occur. Differences in concentration of radioactive material in healthy versus abnormal body tissue eventually produce a pattern, one dot at a time.

On the average, accumulating a picture of 300,000 dots will take around six minutes.

Generally, a variable persistence monitor, capable of detecting movement such as blood flow, serves as a viewfinder on Gamma cameras. A high resolution monitor is then used for taking photographs to be used in diagnosis.

Other application areas

In addition to the raster scan of the Auger microprobe and the random scan of the Gamma camera, display monitors are often used to show graphs, line drawings, groups of characters, or a combination of such things. These displays, capable of showing large amounts of information in their most useful form, are usually computer produced.

The diversity of information that can be shown on display monitors makes them valuable tools for many application areas. These include:

Electrical/Electronic
Waveform Monitoring
Video Tape Monitoring
Flying Spot Scanners
Pulse Height Analyzers
Spectrum Analysis
Radar
Network Analysis

Mechanical
Sound and Vibration
Analysis
Machine Rotation Analysis
Ultrasonic Flaw Detection
Sonar
Acoustic Systems Analysis

Computer

Alphanumeric Readout
Graphs and Line Drawings
Flight Simulation

Medical

Nuclear Scanning
Ultrasonic Scanning
X-ray Intensification
Thermographic Scanning
(Infra-red)

Electro-Optic

Electron Microscopes
Electron Probes
Mass Spectrometers
Chemical Analysis

If you work in any of these fields, or supply equipment to such people, you may need to know about display monitors. An understanding of their characteristics will be helpful in comparing monitors and choosing the one best suited to your particular job. Display monitor characteristics important to you in your application may include any or all of the following:

Long persistence phosphors versus storage.

Light that comes from a phosphor particle being struck by an electron beam continues to be emitted for a while after the electron beam is cut off. How long it continues is referred to as persistence and depends mostly on the kind of phosphor used. At best, however, persistence resulting from phosphor characteristics will be limited to only a few seconds. Two kinds of display monitors offer greater signal retention capabilities —

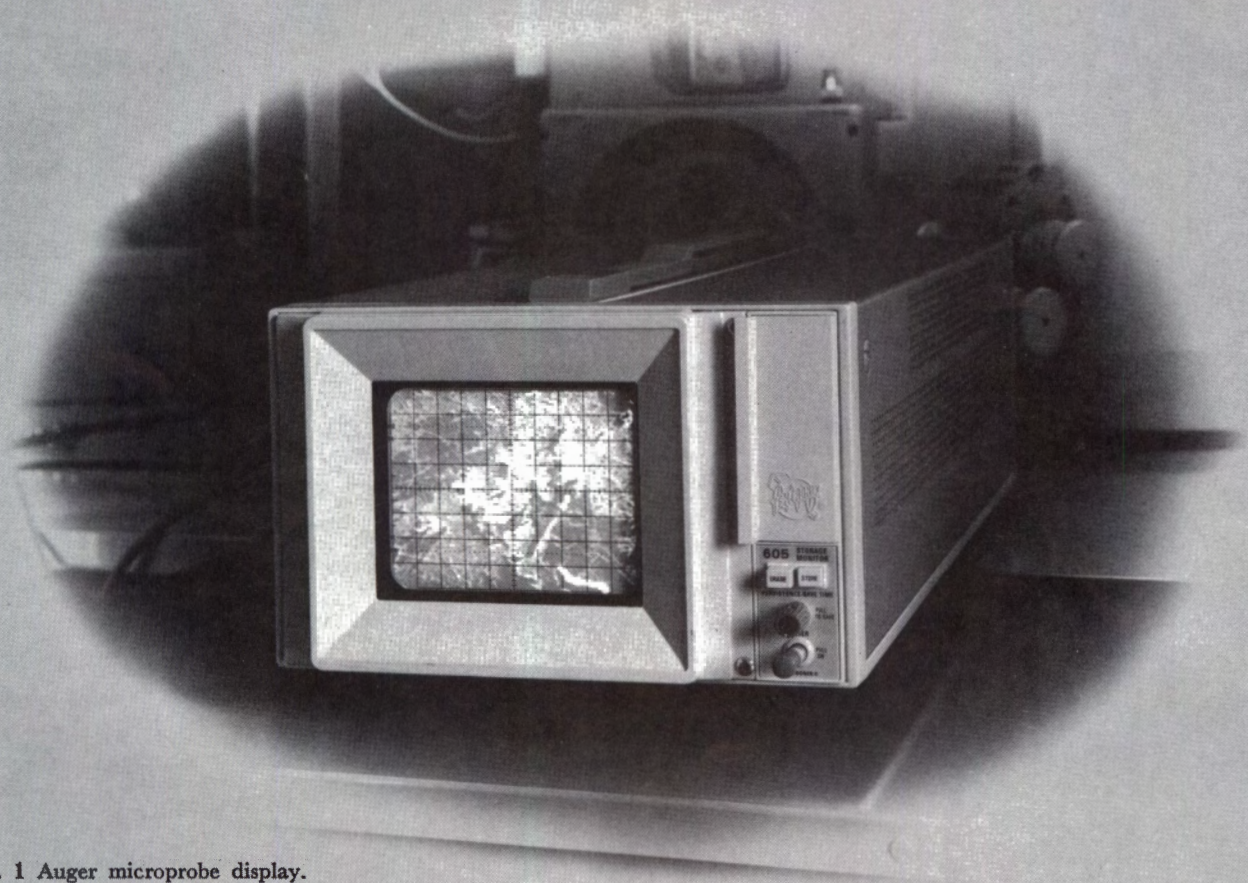


Fig. 1 Auger microprobe display.

bistable storage monitors and variable persistence storage monitors.

With a bistable storage monitor, a trace or dot will last for hours at the original intensity. This is important when you are working with a single-transient event, such as in seismic analysis or mechanical shock testing, and need to view the signal for an extended period of time.

Variable persistence monitors can be adjusted to fade slowly, or rapidly, as the application requires. Any repetitive operation in which you would like to have the signal fade as it is being retraced, such as in engine analysis, thermographic scanning, and radar and sonar displays, are ideal for these instruments. Both bistable and variable persistence monitors may be operated in the non-store mode.

Resolution: trace width, spot size, number of lines.

In some applications, the number of lines on a screen may be more important than the size of the viewing area. For example, where a camera is being used with the monitor, film can be enlarged. On the other hand, immediate visibility is important when a number of people would like to view the screen simultaneously during the scan. When you compare the width of a trace, with the width or height of the crt screen, you can estimate how many parallel vertical or horizontal traces (lines) you can squeeze onto the screen.

The width of a trace is related to the diameter of the spot (crt beam) that produces it. However, high beam current produces a brighter, broader trace than low beam current. Spot size increases as beam current increases, so beam current should be stated when spot size is specified.

The spot of light produced by a crt beam does not have a clearly recognizable edge. Viewed through a microscope, you can see that the center is brightest and that the intensity gradually diminishes near the edges. A cross section of a well-focused spot usually has close to a Gaussian, or bell-shaped, distribution. It has become accepted practice to base spot diameter measurements on the distance across the middle, between the two points where light intensity falls to 50% of peak intensity.

Trace width is usually determined by a shrinking raster technique. A group of well-focused, clearly-separated, parallel traces are positioned closer and closer together until they appear to merge.

As the lines merge when shrinking a raster, there will be a decrease in the difference of light intensity between peaks and valleys. At the point where the intensity of the valleys is about 60 to 65 percent of the intensity of the peaks, you reach the practical limit to the number

of lines which the human eye can distinguish.

Since the space between traces is darker, some people count the dark spaces as lines too. If you include both "dark lines" and light lines in a specification there will be twice as many lines as traces, so the term line-pair is sometimes used to avoid misunderstanding.

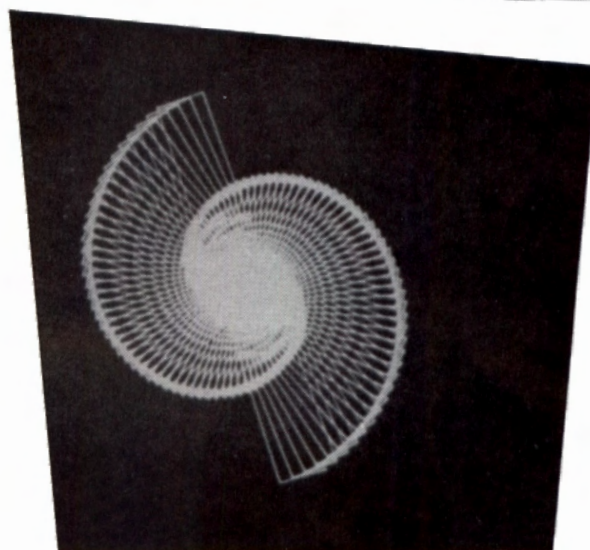
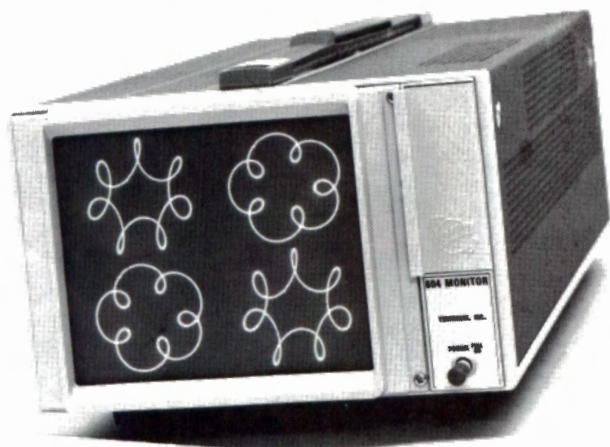
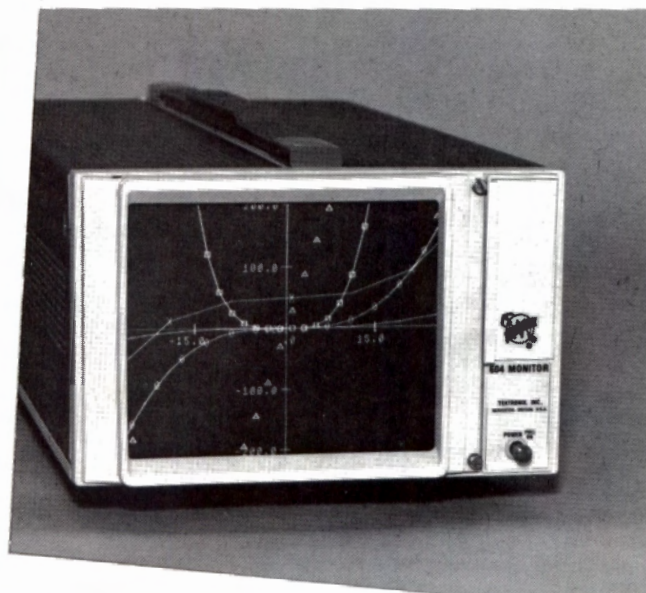
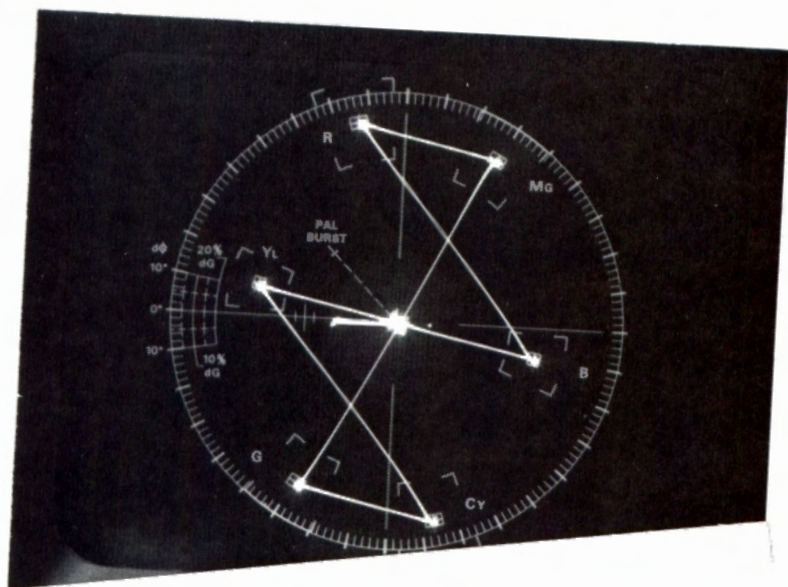
Writing speed, dot writing time, luminance

In a conventional crt, the term "writing speed" may pertain to either the speed at which a spot can move and produce enough light to be photographed during one pass across the screen, or the relative ease with which a fast, slowly repeating trace may be seen on one crt versus another. When the term is applied to a storage crt, it refers to the speed at which a spot may move and still produce a stored trace with only one pass. There will be a difference in the brightness of a fast trace that is barely stored and a slow trace, however. And the difference is displayed more dramatically with variable persistence storage than with bistable storage. As a result, there are more shades of grey (half tones) between the brightest and dimmest stored traces for variable persistence storage than for bistable storage. With variable persistence storage, writing speed can be improved at the expense of storage time, and storage time should be stated or graphed anytime writing speed is specified.

When a display is continually and rapidly changing, as on a TV screen, storage crts are of little use. But when slowly changing information can't be written and refreshed often enough to eliminate flicker, the display can be very fatiguing to observe and a storage crt becomes worthwhile. In a situation where a computer, or computer terminal, is required to produce a refreshed display, it must have a lot of costly additional memory capacity. Storage tubes then have an advantage in retaining and displaying computer-processed information.

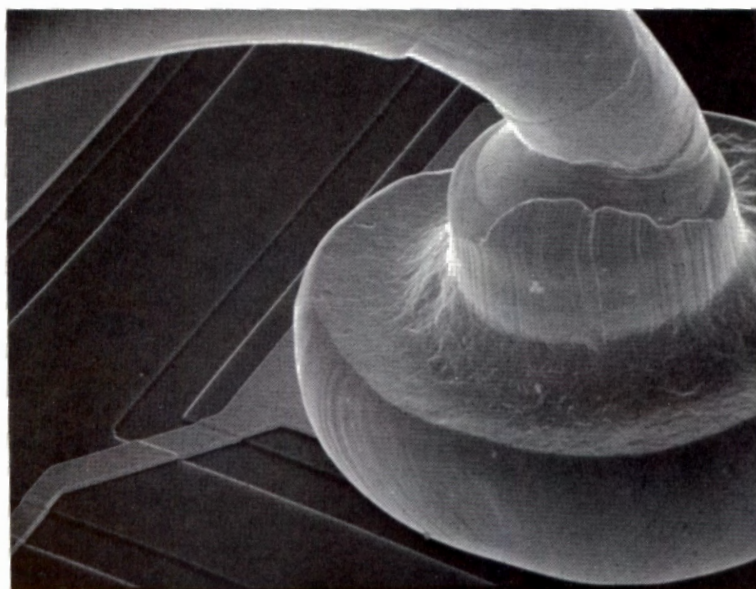
Dot writing time is the time necessary to store a spot produced by a crt beam that is not moving. It is important when a display is produced from a series of dots instead of traces, as with the Gamma camera. Settling time, discussed later, is also an important specification for displays made from dots. Dot writing time and settling time, taken together, determine the maximum rate at which you can produce a clean stored display using binary data.

Luminance is a quantitative term for brightness as perceived by the human eye and is dependent on color and the type of crt phosphor. Brightness of the display governs how easy it is to see when ambient light is comparatively bright. When room lighting can't be reduced, the proper light filter can improve viewing ease, for several reasons. First, because light from the room



HIGH DENSITY ALPHANUMERICS

X	SIN X	COS X	ARCTAN X
0.1000	0.0998	0.9950	0.0997
0.2000	0.1987	0.9801	0.1974
0.3000	0.2955	0.9553	0.2915
0.4000	0.3894	0.9211	0.3895
0.5000	0.4794	0.8776	0.4794
0.6000	0.5642	0.8253	0.5637
0.7000	0.6442	0.7649	0.6404
0.8000	0.7174	0.6967	0.6187
0.9000	0.7833	0.6216	0.6748
1.0000	0.8415	0.5403	0.7328
1.1000	0.8912	0.4536	0.7954
1.2000	0.9320	0.3624	0.8330
1.3000	0.9636	0.2675	0.8761
1.4000	0.9855	0.1700	0.9151
1.5000	0.9975	0.0707	0.9506
1.6000	0.9996	0.0292	0.9828
1.7000	0.9917	0.1208	1.0122
1.8000	0.9739	0.2272	1.0391
1.9000	0.9463	0.3233	1.0637
2.0000	0.9093	0.4162	1.0863
2.1000	0.8632	0.5049	1.1072
			1.1264



has to pass through the filter twice to be observed, once in each direction, whereas light from the crt beam passes through only once. And, second, a colored light filter that matches the spectrum of light from the crt phosphor tends to blank out other colors.

X-, Y-, and Z- Axis characteristics

The electrical characteristics of a display monitor are important when you want to know how easy it is to adapt the monitor to the equipment with which it will be used. The input RC (resistance and capacitance) tells you the kind of load your equipment must be able to drive. The VOLTS/DIV tells you how much signal voltage your equipment must supply to drive the X and Y amplifiers to full-screen deflection. The bandwidth tells you how well the amplifier will respond to high frequency signals, or signals with a short risetime. Deflection linearity indicates how precisely a graph or picture may be displayed. The nonlinearities are usually most severe near the edges of the screen.

For some applications, display monitor amplifiers should have two (differential) inputs for the X-, Y-, and Z- Axis inputs.

The purposes of differential inputs are: (1) to accommodate push-pull signals, if that should be what your equipment supplies, and (2) to prevent unwanted signals that are common to both inputs, from producing deflection. How well any common-mode signal is rejected is termed the common mode rejection ratio (CMRR). With a CMRR of 100:1, only 1% as much deflection would be produced by a signal common to both inputs as by the same signal applied to one input only.

The phase difference between the vertical and horizontal deflection amplifiers indicates the relative amount of spot position error that may exist at any instant, when high-frequency signals at the inputs to both


amplifiers are controlling deflection.

Settling time is another important display monitor characteristic. It is determined by the risetime and transient response of the X and Y amplifiers. Risetime, the ability to faithfully follow a fast change in voltage, is related to bandwidth, and is defined as the time it takes an amplifier to change between 10% and 90% of the distance between two fixed voltage levels, when the input level is suddenly switched. Overshoot and ringing are transient response distortions that can occur following switching.

In random scan applications, where the beam is usually turned off when being switched from one position to another, overshoot and ringing can cause significant image distortion if the beam is unblanked prematurely. For this reason, specified settling time usually includes risetime and time for transient response distortions to settle out. When the beam is within one spot diameter of its final position, it is considered close enough for most applications.

An important factor in applications where beam intensity is modulated instead of being merely turned off or on, as in the Auger microprobe discussed earlier, is the grey scale capability of the instrument. Again, variable persistence monitors offer the maximum grey scale capability.

Summary

While, at first glance, selecting a display monitor for your application may appear relatively easy, this article should have illustrated that there are a number of considerations "behind the looking glass." TEKTRONIX display monitors can provide an economical, very accurate, and straightforward solution to a wide variety of information display needs. To further assist you in selecting the proper monitor, we encourage you to write for our booklet entitled "Display Monitors." 

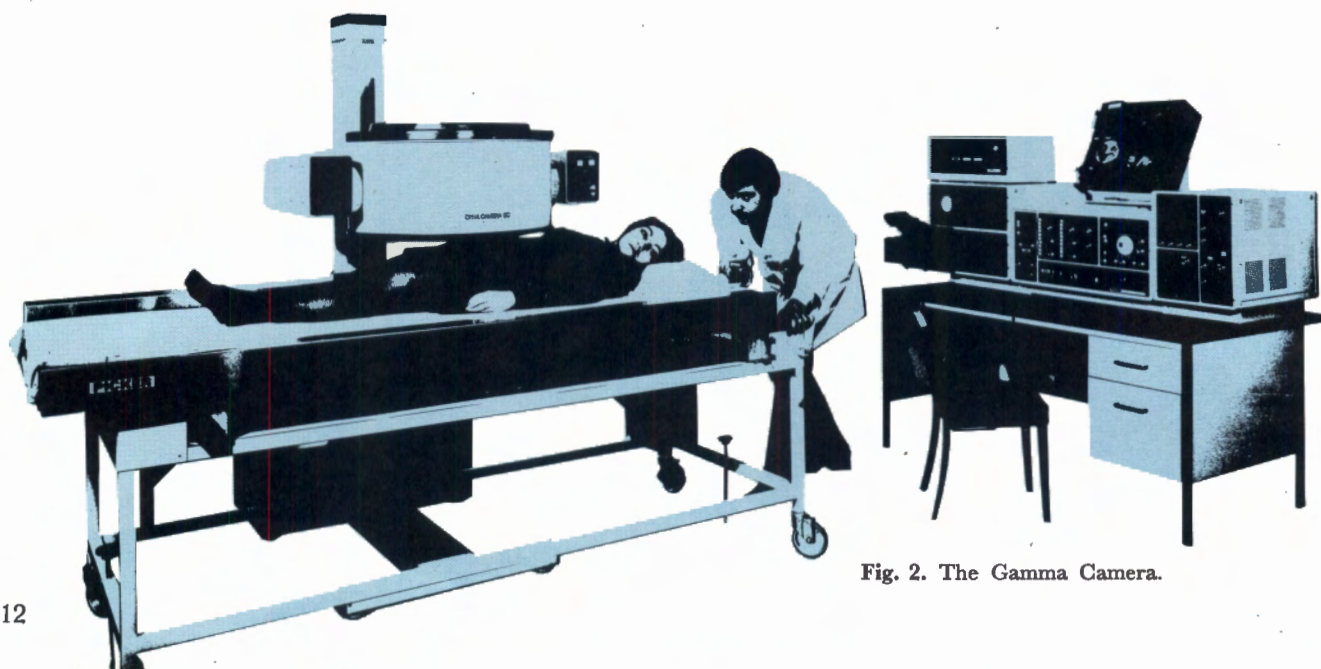


Fig. 2. The Gamma Camera.



Neil Martin

Repairing pushbutton switches

Some call the time we're living in, "the pushbutton age". And rightly so. If you don't agree, just take a look at the front panel of a typical modern oscilloscope. You can count at least a dozen pushbuttons, and probably more.

Pushbutton switches are very reliable devices. And it's a good thing they are, considering the number in use. But you will encounter an occasional failure even in reliable devices, and pushbutton switches are no exception. Let's take a look at the types of pushbutton switches used in Tektronix instruments, what kind of troubles you may experience, and how to go about correcting them.

Most pushbutton switches used in our instruments are manufactured by Tektronix, Centralab, or Grigsby. Those built by Tektronix are sealed and it is not feasible to repair them, so we'll concern ourselves with those manufactured by Centralab and Grigsby. It is easy to tell them apart—the Centralabs have black or blue housings, while the Grigsbys are red. The basic switch action is the same for both kinds, with minor differences in the latching mechanisms and contact shape. The movable contacts are mounted on a plastic plunger, and make contact with fixed silver-plated pins that pass through the switch body and extend on both sides. These pins are often soldered directly into a circuit board, serving as the switch mounting as well as the fixed contacts.

Types of switches

There are three basic types of pushbutton switches used in Tektronix instruments: a momentary contact switch used for such functions as beam finder and single sweep reset; the push-push switch used for functions such as $+$ or $-$ slope, and ac or dc coupling; and a series of interlocking, or self-cancelling, switches used for such functions as vertical and horizontal display switching. All three types of Centralab switch are shown in Fig. 1. Switches (a), (b), and (c) are interlocking switches. Note the latching notches in the plunger near the front of the switch body. Switch (d) is a push-push switch. Note the absence of latching notches in the plunger, and the flat spring at the top front of the switch. Under this flat spring is a pin that fits into a channel in the plunger (see Fig. 3). It is this pin, spring, and channel that provide the push-push action. Switch (e) is a momentary contact switch and lacks the latching notches, the pin, and the flat spring. The black ring at the front of the switch body limits the plunger travel.

Typical problems

Before taking the switches apart and examining how they work in detail, let's discuss some of the operating problems you may experience. The most common is intermittent operation. This can often be cured by spraying No Noise in the back end of the switch, while working the switch. This should remove any foreign material from the contacts.

Bent or badly worn contacts are the next most likely cause of intermittent operation. It will be necessary to disassemble the switch to examine the con-

tacts, and we'll discuss how to do that shortly. Another condition that can occur is an interlocking switch may fail to latch in. This could be caused by a weak latch bar spring or a sticking latch bar. A push-push switch can fail to latch in if the spring holding the pin in position becomes weak or bent. The remedy for these problems is to bend the spring so it supplies sufficient tension, or replace it. Rough operation may be caused by bent contacts, lack of lubrication on the plunger, or a small burr on one of the parts.

To cure most of these problems, you will have to take the switch apart. A small screwdriver and a short pair of long nose pliers are all the tools you need. Small hands, a degree of manual dexterity, and patience are also helpful. We suggest you have a good switch on hand to use for replacement parts. You may wonder, "why take parts from a good switch and put them in an old switch?" That's a logical question, and the reasons are that it's much quicker to replace the parts, and you eliminate the possibility of damaging the printed circuit board when removing and soldering in the new switch.

Taking them apart

Now let's take a look inside the switches. If you have a spare switch, it will be helpful to examine it and practice taking it apart and reassembling it. You will

find it to be a relatively simple operation, and also learn to hold onto the springs while removing and installing the keepers as the springs have a tendency to suddenly take off into space and roll out of sight.

To disassemble the push-push switch refer to Figure 2. Use the small screwdriver to remove keeper (a); remove spring (b); and remove pin (d). The plunger (f) can now be slid out the rear of the switch body (e). As you push the plunger slowly to the rear you will see the contacts start to appear. You should hold them in place with the thumb and middle finger so you can examine how they are mounted in the plunger. The contacts are item (g) in Figure 2.

Figure 3 is a close-up of the plunger showing the channel the pin traverses. The pin travels the path shown by the dashed arrow when the button is pressed and remains in. The solid arrow shows the path when the button is pressed and releases.

The Grigsby version of the push-push switch has essentially the same action as the Centralab. The only difference between a push-push and an interlocking contact switch in the Grigsby is the length of the pin. The shorter pin is used in the push-push contact switch. The long pin could be left out of the interlocking switch and it would function properly unless it were

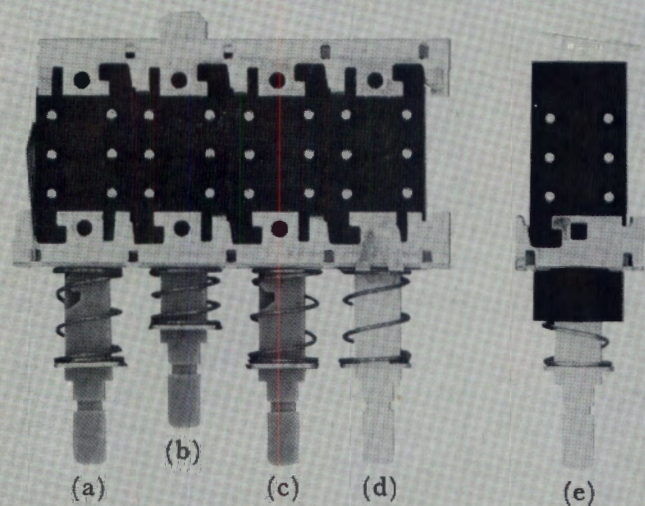


Fig. 1. Three types of Centralab switches are shown above. (a), (b), (c) are interlocking, (d) is push-push, and (e) is momentary contact.

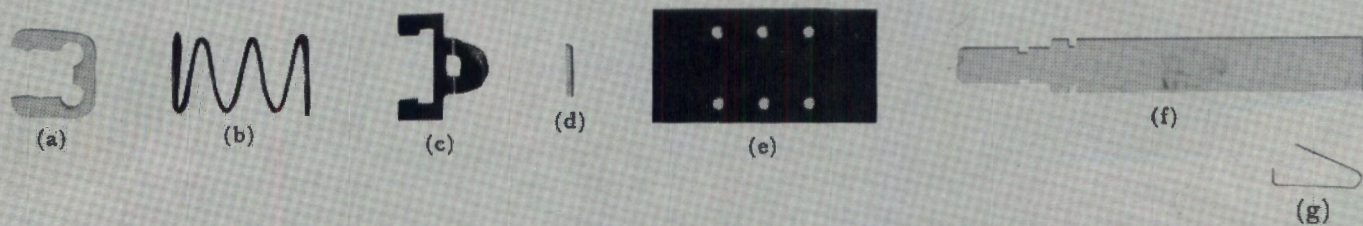


Fig. 2. A Centralab push-push switch disassembled. Components are: (a) keeper, (b) plunger spring, (c) pin spring, (d) pin, (e) body, (f) plunger, and (g) contacts.



Fig. 3. Plunger from Grigsby switch. Pins travel path shown by dashed line when button is pushed and remains in. Solid arrow shows the path when the button is pressed and releases.

mounted upside down.

A Centralab interlocking switch is shown in Figure 5. Note the latching bar spring in the end view. The additional steps in disassembling this type of switch involve removing the latching bar spring, carefully unbending the tabs on the front and rear keeper frames, and sliding the frames slightly to the side. Carefully remove the keeper frames and note the orientation of the latch bar, and the spacers in the rear keeper.

The interlocking switch works as follows: When the pushbutton is depressed, the first plunger notch pushes against the latch bar (d) in Figure 5, and the latch bar pushes against the latch bar spring (e). When the latch bar reaches the peak of the notch, the latch bar releases the other switches. As you depress the switch further, the latch bar spring forces the latch bar into the second slot, which holds the switch into position. Spacers (b) located in the rear keeper frame (a) prevent two switches from being pressed in at the same time. This is called lockout.

The Grigsby interlocking switch operates in the same manner as the Centralab but uses a different shaped latch bar spring, and the latch bar is located in the bottom of keeper (a) in Figure 6 instead of behind keeper (f) as in Figure 5.

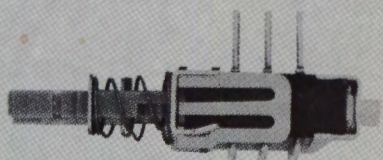


Fig. 4. End view of Centralab interlocking switch showing latch bar spring.

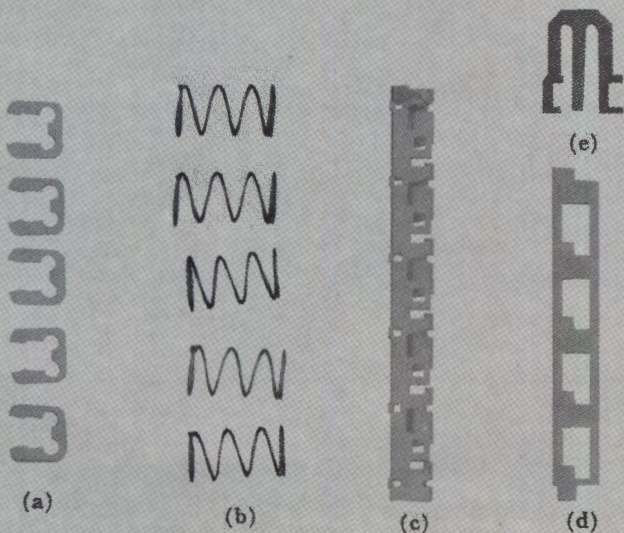


Fig. 5. A Centralab interlocking switch partially disassembled. Items (d) and (e) are the latch bar and latch bar spring. Item (g) prevents two switches from latching in simultaneously.

It is relatively easy to replace a single Grigsby interlocking switch as all you have to do is remove the keeper, spring, and pin spring, unsolder the switch, and lift it out of the assembly. The remaining switches can be left in place.

Conclusion

It is much easier to repair pushbutton switches than it is to replace them. Many can be repaired without removing the printed circuit board on which they're mounted. Often the task of removing and installing the circuit board takes more time than repairing the switch. If you find it necessary to replace the switch, it is usually easier to cut the mounting pins and remove them one at a time from the circuit boards.

You may have been hesitant in the past to attempt to repair pushbutton switches. It's not really as difficult a task as it may appear.

We trust these brief service hints will help make your life in this "pushbutton age" more enjoyable, and productive.

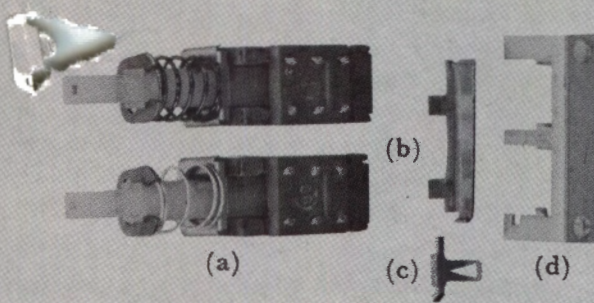
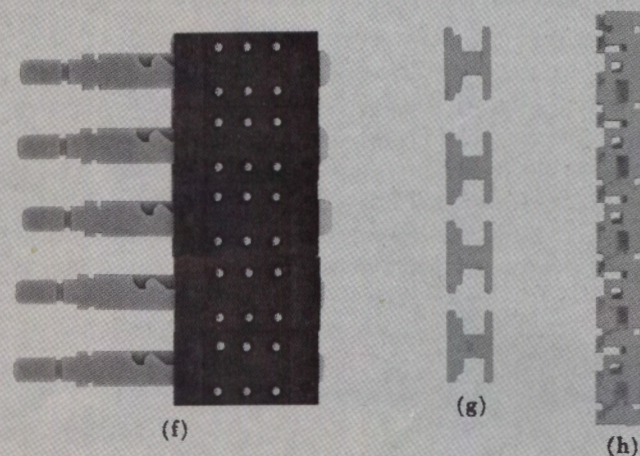


Fig. 6. A Grigsby interlocking switch partially disassembled. Items (b) and (c) are the latch bar and latch bar spring.



New products New products



A Portable Test and Measurement System

A new portable mainframe, the TM 515, and a new oscilloscope plug-in, the SC 502, in combination with the rest of the TM 500 family of plug-in instruments offer a new concept in portable instrumentation.

The TM 515 Traveler mainframe accommodates five plug-ins, or modules, and is electrically similar to other TM 500 mainframes. However, its design has been optimized for portability. It is lightweight, rugged, and attractive. With end covers on, it has the appearance of quality luggage. The covers provide protection for the instrument front panels and the ventilating fan, and serve as storage compartments for the bail and power cord. Accessories or tools can also be stored in the covers.

The SC 502 is a two-compartment wide, dual trace oscilloscope that offers a combination of features not found on any other oscilloscope. Bandwidth is 15 MHz from 20V/DIV to 5 mV/DIV, 10 MHz at 5 mV/DIV, and 5 MHz at 1 mV/DIV. The risetime is 23 ns.

Accelerating potential is 12kV, providing a higher visual writing rate than some 50 or even 100 MHz instruments. High writing rate is very useful in those portable applications where the instrument is to be used outdoors, or anywhere the ambient light level is high. And it makes the SC 502 ideal for those low repetition rate signals commonly encountered in service applications, particularly, digital service applications.

New T900-Series Oscilloscope

T900 Oscilloscopes are an entirely new line designed for cost savings without sacrifice of basic performance. They offer the quality, reliability, and support traditionally associated with TEKTRONIX Oscilloscopes — all at a moderate price.

This new line includes:

- T921—DC to 15 MHz; single trace, mono time base
- T922—DC to 15 MHz; dual trace, mono time base
- T932—DC to 35 MHz; dual trace, mono time base
- T935—DC to 35 MHz; dual trace, dual time base with delayed sweep
- T912—DC to 10 MHz; dual trace, mono time base, bistable storage

All of the T900's have a large (8 x 10 cm) screen with internal graticule. The four nonstorage models use a 12 kV accelerating voltage in a post-accelerator crt, providing bright displays of low-rep-rate signals, even under adverse lighting conditions. Stored writing speed of the T912 extends up to 250 cm/ms.

Measuring only 7" x 10" x 19", the T900-Series oscilloscopes take little space on the production line or work bench. Lightweight (15-18 lbs), compact, with a protective front panel cover and impact-resistant plastic case, T900 instruments can be hand-carried, transported, or shipped with little care and effort. Carefully selected controls, and color-coded front panels shorten familiarization time and aid in easy operation.



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